Journal of Economics and Business Letters
E-ISSN 2686-6056
P-ISSN 2798-8651
https://doi.org/10.55942/jebl.v5i5.782

Volume 5
Issue 5
October Edition 2025

Climate change, resource degradation, and economic sustainability: A study of key commodity sectors in Southern Sumatra

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Received 01 September 2025
Revised 28 October 2025
Accepted 30 October 2025

ABSTRACT

Climate change is one of the biggest challenges facing the world today. This phenomenon has significantly impacted the degradation of natural resources, posing a serious threat to the agricultural and fisheries sectors, especially in developing countries. Climate change affects the structure of land and water and directly impacts the potential sectors in a region. The primary objective of this study is to quantitatively analyze the impact of climate change on resource degradation across the leading commodity sectors, namely agriculture, plantations, and fisheries in the Southern Sumatra region. This research adopts a mixed-methods approach, integrating multiple regression analysis using regional data from 2015 to 2022 with a Sharing Group Discussion (SGD) component to ensure contextual validation and deeper insights. The findings indicate that six meteorological factors (wind speed, rainfall, solar radiation, air temperature, air pressure, and humidity) significantly influenced degradation within these three crucial sectors. Ultimately, this study offers a forecasting overview of the climate impacts on specific commodity sectors, providing a crucial basis for stakeholders to formulate anticipatory policies, plan appropriate technological adaptation, and implement more effective resource management strategies to address the challenges of climate change.

Keywords: Agriculture, Fisheries, Plantation, Climate Change, Southern Sumatra

1. INTRODUCTION

Climate change has emerged as a fundamental challenge worldwide. This phenomenon has significantly accelerated natural resource degradation, even posing a serious threat to the sustainability of the agricultural and fisheries sectors, particularly in developing countries (Vermeulen et al., 2012). These climatic impacts manifest as shifts in weather patterns, rising global temperatures, and an increased frequency of extreme weather events. Such conditions demonstrably affect the productivity and resilience of these sectors (Pautasso et al., 2012; Srivastava & Misra, 2018; Zagaria et al., 2023). Furthermore, rising global temperatures and shifts in rainfall patterns contribute to the increasing intensity of disasters, such as floods, droughts, and forest fires, which directly exacerbate the degradation of land, water, forests, and biodiversity. In line with this (Seidl et al., 2017) predict that forest degradation will increase globally, particularly in tropical and subtropical regions. Moreover, sustained temperature increases and prolonged drought have resulted in mass tree mortality in several areas (Allen et al., 2010) and the risk of land degradation is projected to continue escalating. In addition, climate change is expected to increase the risk of land degradation in many regions, especially in arid and semi-arid areas (Olsson et al., 2022). For example, increasing global temperatures and changes in rainfall patterns will increase soil erosion (Borrelli et al., 2016). Climate change has affected the hydrological cycle, causing changes in rainfall patterns and increasing the frequency and intensity of floods and droughts. Apart from that, this phenomenon will also have an impact on water availability and quality, as well as increasing the risk of degradation of water resources (Jiménez-Cisneros et al, 2014).

The effects of climate change are not limited to the structure of land and water but directly affect potential sectors within a region, such as agriculture (Harini et al., 2022), plantations, and fisheries. In the agricultural sector, climate change has disrupted rainfall patterns, elevated the risk of floods and droughts, and altered the distribution of pests and diseases. These conditions collectively diminish agricultural productivity and threaten global food security. Study showed project a decline in the production of major food crops across many regions, particularly in vulnerable tropical and subtropical areas (Challinor et al., 2014). Furthermore, rising global temperatures have been shown to reduce yields of wheat, rice, and corn in several countries (Zhao et al., 2017). Similar implications are observed in marine (Barange et al., 2018; Cinner et al., 2022) and freshwater (Illahi et al., 2023), which in turn impact the fisheries sector. Climate change can cause shifts in fish species distribution, decrease fisheries productivity (Moegni et al., 2014), and eighten the risk of damage to marine habitats (Cinner et al., 2022). Overall, global warming and ocean acidification pose a serious threat to the sustainability of the fisheries sector in various regions worldwide (Blasiak et al., 2017).

Table 1. Development of Agricultural, Plantation and Marine Fisheries Commodity Production in SUMBAGSEL in 2020-2021 (Thousand Tons)

Comodities	Year	Province				
		Bengkulu	Jambi	Sumatera Selatan	Lampung	Bangka Belitung
Paddy	2021	271.117	298.149	**355.443**	**2485.453**	70.496
	2022	281.61	277.744	**2775.069**	**2688.16**	61.425
Palm Oil	2021	1151.654	2637.194	**3181.39**	420.715	800.362
	2022	730.39	2600.843	**3449.202**	202.216	793.456
Rubber	2021	97.875	**301.022**	**882.889**	131.422	**47.79**
	2022	90.11	**303.169**	**1206.192**	192.395	**49.845**
Coffee	2021	62.849	**19.222**	211.681	**116.218**	**0.039**
	2022	56.03	**19.831**	206.307	**118.139**	**0.04**
Marine Fisheries	2021	**76.773**	**54.857**	117.74	138.453	**244.964**
	2022	**77.036**	**55.77**	128.448	133.76	**265.068**

Sources: Author's calculation based on BPS and SLHI data, 2025

The plantation sector is also not immune to the impacts of climate change. Changing rainfall patterns, increasing temperatures, and extreme weather events, such as droughts and floods, can affect the productivity and sustainability of plantations. The study of (Abubakar et al., 2021; Alam et al., 2014; Ardiani et al., 2022; Junaidi., 2019; Entezari et al., 2021; Idawati et al., 2018; Sianipar, 2021; Junaedi et al., 2021) found that climate change has had a negative impact on the production of major plantation crops such as oil palm, rubber and cocoa in several tropical countries. Increasing temperatures and changes in rainfall patterns cause a decrease in crop yields and the quality of plantation products (Keenan, 2015; Watt et al., 2019). Likewise, the same thing happens to the production of the coffee plant sector due to climate change (Angka, 2021; Sarvina et al., 2020).

Southern Sumatra, also called SUMBAGSEL, has potential commodities in the agricultural, plantation, and marine fisheries sectors. Table 1 shows the development of agricultural commodity production (rice), plantations (oil palm, rubber, and coffee), and marine fisheries in 2020-2021. For the most part, commodity production experienced a relative contraction from the previous year, such as in Bengkulu Province for palm oil, rubber, and coffee. Even though this commodity is one of the most potential commodities in Bengkulu Province. However, rice and marine fishery commodities experienced an increase in production. In addition, South Sumatra experienced a contraction in coffee, rice, and marine fisheries commodities. However, there has been an increase in palm oil and rubber commodity production. Rubber commodities experienced an increase in four provinces: Jambi, South Sumatra, Lampung, and the Bangka Belitung Islands.

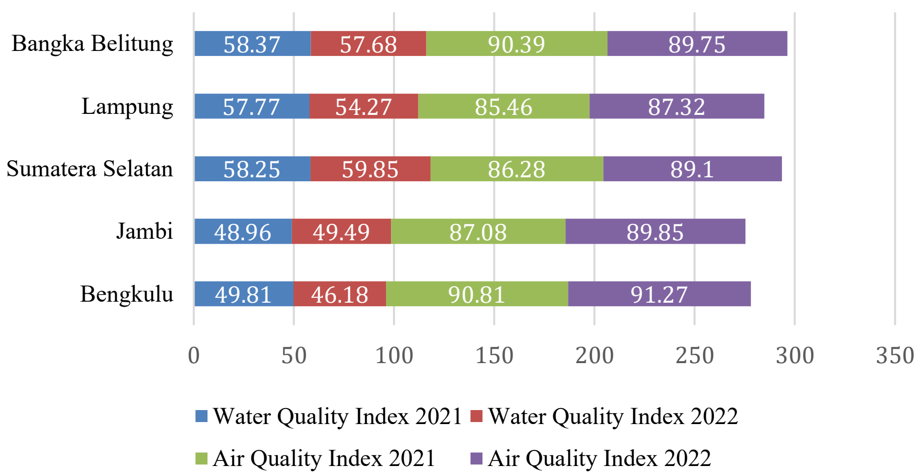


Figure 1. Development of the Water and Air Quality Index in SUMBAGSEL 2020-2021

Sources: Author's calculation based on SLHI data, 2025

In contrast, the climate changes that occur in the SUMBAGSEL region are relatively good or above the normal climate average. However, there are several contractions in the index numbers. Figure Figure 1 shows that the water quality index improved only in the provinces of South Sumatra and Jambi. Meanwhile, other provinces experienced a contraction or decline in the water quality index. In addition, the air quality index shows that only the Bangka Belitung Islands Province experienced a decline in air quality. Meanwhile, the air quality index improved in Bengkulu, Jambi, South Sumatra, and Lampung provinces in 2021. Therefore, based on the challenges and threats of climate change, it is important to analyze the impact of climate change on potential sectors, especially in the agricultural and plantation sectors. and fisheries, which are among the largest commodities in developing countries, especially in the Southern Sumatra region.

2. METHODOLOGY

This study employs a mixed-methods approach that integrates quantitative panel data analysis with qualitative evidence to strengthen the interpretation of the results. The quantitative component uses a multiple linear regression model with provincial panel data for 2015–2022. The data sources used were obtained from published reports from the Central Statistics Agency (BPS) for each province and Indonesian Environmental Statistics (SLHI). The unit of analysis used in the research consists of the regional region of Southern Sumatra (SUMBAGSEL), namely Bengkulu, Jambi, Lampung, South Sumatra, and Bangka Belitung Islands Provinces for the period 2015-2022. The type of data used is panel data, namely combined data between time-series data and cross-section data. Time series data are shown for the research period from to 2015-2022. Meanwhile, the cross-sectional data are shown with the regional boundaries used.

In addition, the dependent variable is the volume of potential commodity production per sector, which consists of five (5) commodities, namely the volume of production of rice commodities (agricultural sector), palm oil production, coffee production, rubber production as a plantation sector, and marine fisheries production as a sector indicator. fishery. Meanwhile, the independent variables are data on the amount of rainfall, amount of sunlight, air humidity, air pressure and air temperature as indicators of climate change. Climate variables (temperature, rainfall, pressure, humidity, radiation, and wind), representing provincial annual averages, were computed from multiple BMKG weather stations. Solar radiation (%) refers to the ratio of actual sunshine hours to the possible sunshine hours per year. All variables were checked for consistency and outliers before aggregation. The analytical methods used are descriptive analysis and multiple linear regression analysis (Wooldridge et al., 2016). Regression analysis aims to analyze the influence of climate change on potential commodity production, including the agricultural, plantation, and marine fisheries sectors. Multiple linear regression is also accompanied by a robustness test to test the robustness of the test in the testing process so that the research results obtain a good level of validity and are not biased (Wooldridge et al., 2016). The following research analysis model equation is as follows:

$$Paddy_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 \text{Air\_pressure}_{it} + \beta_3 \text{Wind\_velocity}_{it} + \beta_4 \text{Humidity}_{it} + \beta_5 \text{Rainfall}_{it} + \beta_6 \text{Radiation}_{it} + \varepsilon_{it} \quad (1)$$

$$Palm\_oil_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 \text{Air\_pressure}_{it} + \beta_3 \text{Wind\_velocity}_{it} + \beta_4 \text{Humidity}_{it} + \beta_5 \text{Rainfall}_{it} + \beta_6 \text{Radiation}_{it} + \varepsilon_{it} \quad (2)$$

$$Rubber_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 \text{Air\_pressure}_{it} + \beta_3 \text{Wind\_velocity}_{it} + \beta_4 \text{Humidity}_{it} + \beta_5 \text{Rainfall}_{it} + \beta_6 \text{Radiation}_{it} + \varepsilon_{it} \quad (3)$$

$$Coffee_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 \text{Air\_pressure}_{it} + \beta_3 \text{Wind\_velocity}_{it} + \beta_4 \text{Humidity}_{it} + \beta_5 \text{Rainfall}_{it} + \beta_6 \text{Radiation}_{it} + \varepsilon_{it} \quad (4)$$

$$Marine\_fishery_{it} = \beta_0 + \beta_1 Temp_{it} + \beta_2 \text{Air\_pressure}_{it} + \beta_3 \text{Wind\_velocity}_{it} + \beta_4 \text{Humidity}_{it} + \beta_5 \text{Rainfall}_{it} + \beta_6 \text{Radiation}_{it} + \varepsilon_{it} \quad (5)$$

While logarithmic transformation is a common practice to estimate elasticity, we deliberately chose the linear (level-level) model specification to facilitate the interpretation of coefficients in absolute terms (unit-to-unit). This choice allowed us to present the findings directly as a 1 $^{\circ C}$ increase in air temperature affects the yield by X kg. This interpretation is significantly more digestible for key stakeholders in formulating specific, actionable adaptation policies than dealing with percentage elasticities. Furthermore, all classical assumptions for the level-level model were fully satisfied, indicating that no statistical issues necessitated the data transformation.

To complement the quantitative findings, qualitative information was collected through a Sharing Group Discussion (SGD) conducted by the Regional Office of the Directorate General of Treasury in Bengkulu Province. The discussion involved key stakeholders from relevant agencies, including the Meteorology, Climatology, and Geophysics Agency (BMKG), the Marine and Fisheries Office, the Agriculture Office, and the Environment and Forestry Office. The SGD results were used to contextualize the statistical findings, identify local adaptation responses, and provide policy-relevant insights regarding climate change mitigation and resource management strategies in the region.

3. RESULT AND DISCUSSION

3.1 Result

In describing the results, two stages were carried out: the stage of describing the research data used and the stage of finding determinant factors using regression analysis.

Table 2. Statistic Descriptive on Research Data

Total of observations: 40					
Variables	Unit	Mean	Std. Deviasi	Minimum	Maximum
Paddy production	Thousands of tons	1440.556	1519.993	27.068	5074.613
Palm oil production		1509.889	1164.594	202.216	4267.023
Rubber production		333.925	369.273	47.686	1260.321
Coffee production		75.695	70.371	0.00225	211.681
Fisheries production		130.384	65.486	49.616	265.068
Air temparature	^oC	27.679	0.7955	26.6	29.41
Air pressure	mb	1008.662	3.4378	999.7	1018.4
Wind velocity	Knot	2.9567	1.1047	0.78	5.37
Humidity	Percent	81.609	3.052	76.46	87.58
Rainfall	mm	2635.055	747.522	1534.7	4518.5
Radiation	Percent	59.768	9.3501	44.6	81.25

Note: Radiation (%) refers to the annual sunshine duration as a percentage of possible sunshine hours. Climate variables represent provincial annual means computed from all available BMKG stations, and production variables are expressed in thousands of tons at the provincial level. Sources : Author's calculation based on BPS and SLHI data, 2025

Table 2 presents a statistical description of the research that used 40 data points consisting of eight years and five provinces in the Southern Sumatra region. Apart from that, the variables used are 11 variables consisting of five dependent variables and six independent variables. Table 2 presents a description of the research data used. The results of the description show that the average rice production is 1440,556 thousand tons, the average palm oil production is 1509,889 thousand tons, the average rubber production is 333,925 thousand tons, coffee production is 75,695 thousand tons, and fisheries production is 130,384 thousand tons. Data related to climate change show that the average temperature change reaches 27-28^oC, the average change in air pressure is 1008,662 mb, the average wind speed reaches 2.95 knots, the average air humidity is 81.6 percent, the average rainfall is 2635,055 mm, and the average solar radiation is 59,768 percent. Solar radiation was measured as the annual percentage of possible sunshine hours, representing the ratio between observed sunshine duration and the maximum possible daylight hours per year. The data were obtained from the SLHI aggregated at the provincial level as annual means.

Climate change is an uncertain and fluctuating phenomenon. Based on Figure 2, rainfall growth in South Sumatra experienced fluctuations from to 2016-2022. Bengkulu Province has the highest average annual rainfall growth, namely 17,8593 mm, whereas Lampung has the lowest average, namely 6,2016 mm. The highest rainfall growth occurred in Bengkulu Province in 2020, namely 134.1096 mm, while the lowest annual rainfall growth was also in Bengkulu Province, namely in 2019, amounting to -40.1325 mm. Other provinces in South Sumatra such as Jambi, South Sumatra and Bangka Belitung show moderate annual rainfall growth with less extreme fluctuations.

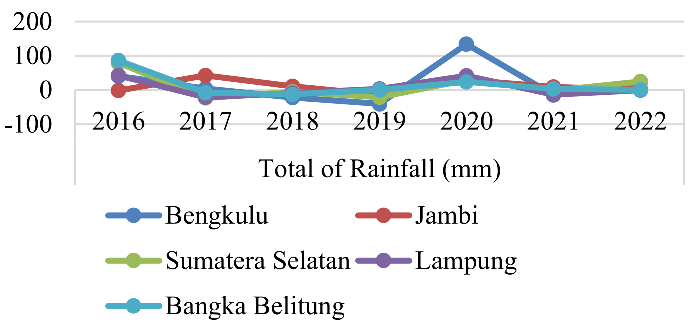


Figure 2. Annual Change in Total Rainfall (mm) from 2016-2022 in SUMBAGSEL

Sources: Author's calculation based on BPS and SLHI data, 2025

Figure 3 illustrates the annual change in mean air temperature (°C) across the five provinces of Southern Sumatra (SUMBAGSEL) during the 2016–2022 period. Overall, the data revealed noticeable interannual fluctuations, with distinct warming trends in certain years, particularly in Bengkulu, South Sumatra, and Bangka Belitung. Bengkulu recorded the largest annual temperature increase of 7.93°C in 2020, followed by a sharp decline of –5.98°C in 2019. A similar pattern was observed in South Sumatra, where temperatures rose by 6.55°C in 2018 but fell by –5.12°C in 2019. In Bangka Belitung, the temperature increased by 6.77°C in 2022 and decreased by –6.67°C in 2019, indicating considerable variability. In contrast, Jambi and Lampung showed relatively stable temperature patterns, with annual changes mostly within the range of –1°C to 1°C.

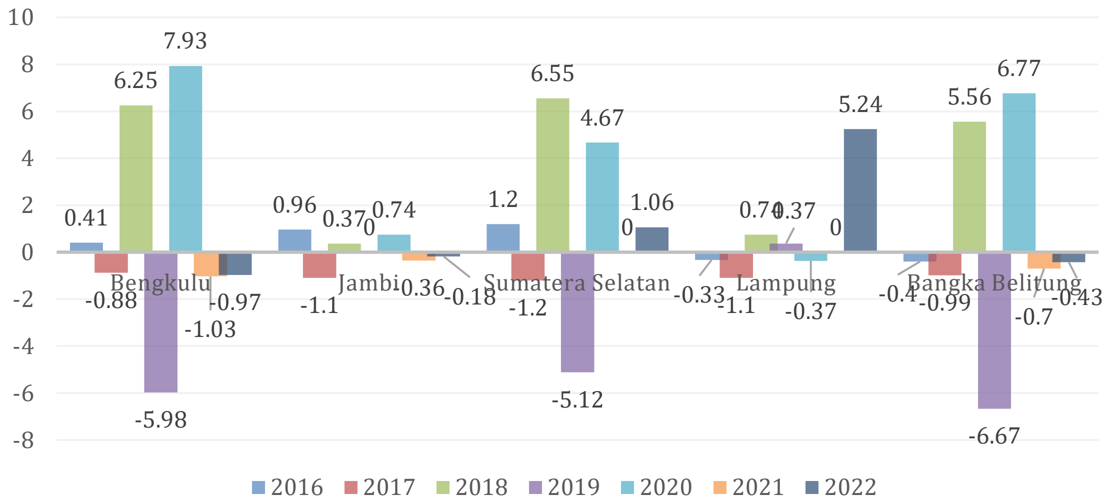


Figure 3. Annual change in Mean Air Temperature (°C) from 2016-2022 in SUMBAGSEL

Sources: Author's calculation based on BPS and SLHI data, 2025

Figure 4 shows the growth in wind speed in South Sumatra between 2016 and 2022. The analysis results showed that the highest average wind speed growth occurred in Bangka Belitung at 3.18 knots, whereas the lowest average growth was recorded in Bengkulu at 0.82 knots. The highest wind speed growth during this period occurred in Bengkulu in 2020, with a value of 7.93 knots. In contrast, the lowest wind speed growth occurred in Bengkulu in 2019, with a value of -5.98 knots. Provinces with high average wind speeds, such as Bangka Belitung, may be more vulnerable to the impact of strong winds, whereas provinces with low average wind speeds, such as Bengkulu, show stability. which is greater than the annual wind speed.

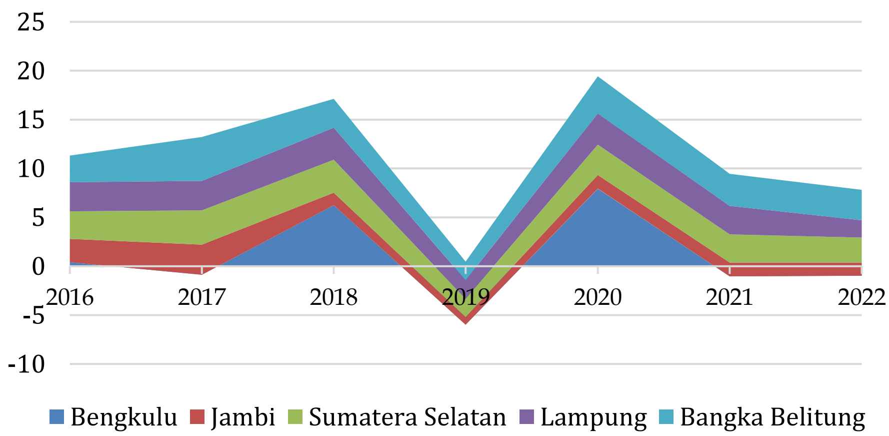
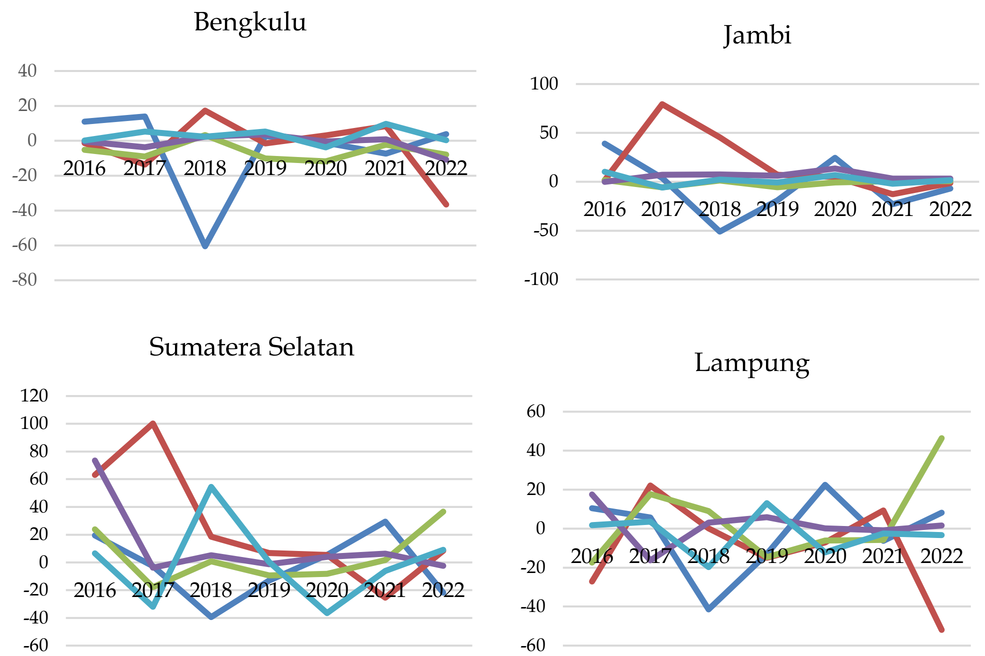


Figure 4. Wind Speed Annual (Knots) from 2016-2022 in SUMBAGSEL

Sources: Author's calculation based on BPS and SLHI data, 2025

Based on Figure 5, the Growth of Agricultural, Plantation and Fishery Commodities in SUMBAGSEL in 2016-2022, you can see variations in growth between each commodity and province. In Bengkulu Province, rice commodities experienced a drastic decline in 2018, amounting to -51.02%, but showed an increase again in 2020, with a growth of 24.68%. Palm oil commodities in Bengkulu achieved the highest growth of 79.40% in 2017, while in 2022 there will be the largest decline of -36.58%. In Jambi, palm oil also showed large fluctuations, with a peak growth of 100.21% in 2017 and the largest decline of -25.44% in 2020. Meanwhile, rubber commodities in Jambi Province showed a significant increase in 2022, with a growth of 36.62%.



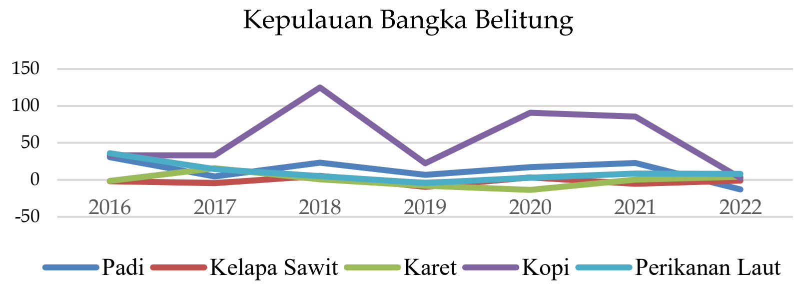


Figure 5. Growth of Agricultural, Plantation and Fishery Commodities in SUMBAGSEL 2016-2022

Sources: Author's calculation based on BPS and SLHI data, 2025

In South Sumatra Province, palm oil commodities experienced high growth in 2017 at 100.21%, although they experienced a significant decline of -25.44% in 2020. Rubber commodities in South Sumatra will experience the highest growth in 2022, amounting to 46.39%. In Lampung Province, rice commodities showed a steady increase, with the highest growth of 29.43% in 2021, even though they experienced a decline of -13.05% in 2019. Marine fisheries in Lampung also show fluctuations with the highest growth of 9.68% in 2021 and the largest decline of -3.79 % in 2020. In Bangka Belitung, coffee recorded the highest growth of 125% in 2018, showing great potential despite fluctuations in subsequent years. Overall, this data shows that while several commodities, such as coffee in Bangka Belitung and palm oil in South Sumatra, show great growth potential. Based on Hausman tests (Table 6), fixed-effects models were preferred for all commodities except palm oil (random effects). Therefore, subsequent interpretations refer to these specifications. The effect of climate change on the production volume of potential commodities is shown by the regression results in Table 5. The results show that solar radiation affects the production volume of marine fisheries (in the fixed effect column as the best model). This indicates that better sunlight increases fish production. When solar radiation increases by one unit, it increases the volume of marine fish production by 10.33 units. Air pressure had a positive effect and rainfall had a negative effect on the volume of rice production in Southern Sumatra. Increasing air pressure by 1 mb increases the volume of rice production by 86.89 tons. However, increasing rainfall by 1 mm will cause a reduction in the volume of rice production by 0.573 tonnes.

Furthermore, in oil palm plantations, the results show that air pressure and temperature positively and significantly influenced oil palm production volume. The higher the air pressure and temperature, the higher the palm oil production volume. Meanwhile, wind speed has a negative influence, namely, the stronger the wind, the greater the decrease in the volume of palm oil production (contraction). In rubber production, using the best model, namely fixed effects, climate change does not significantly influence the volume of rubber production. Meanwhile, on coffee plantations, the results show that air temperature and humidity have a positive and significant effect. This means that when air temperature and humidity rise by one unit (oC and percent), the volume of coffee production will increase by 13.54 and 1.17 tons, respectively. Meanwhile, increasing rainfall will cause a decrease in the volume of coffee production by 0.021 tons.

Table 6 shows the results of the Hausman test, which selects the best model from the panel data regression. The results show that only the dependent variable on palm oil production uses random effects as the best model for the study. Meanwhile, the fixed effect model is used as the best model for the dependent variables, namely rice, rubber, coffee, and marine fisheries production. This model is used as a forecasting estimate chosen to see the magnitude of the influence of climate change on each production of these potential commodities.

Table 6. Hausman Test – Selection of Best Model

Dependent Variable	Prob> Chi²	Model result
Paddy production	0.0033	Fixed Effect
Palm oil production	0.7771	Random Effect
Rubber production	0.0000	Fixed Effect
Coffee production	0.0000	Fixed Effect
Fisheries production	0.0000	Fixed Effect

Sources: Author's calculation based on BPS and SLHI data, 2025

3.2 Discussion

These climatic changes bear significant implications for oil palm production, which is one of Indonesia's key plantation commodities (Abubakar et al., 2021). The optimal air temperature required for healthy oil palm growth and yield ranges ideally from 25–33°C (Keenan, 2015; Watt et al., 2019). When air temperatures rise due to climate change, plant physiological processes, including photosynthesis, respiration, and fruit formation, are disrupted. For instance, research by Paterson & Lima (2018), indicates that an air temperature increase of just 1°C can reduce oil palm fresh fruit bunch (FFB) production by up to 10%. Furthermore, air pressure fluctuations can affect transpiration and water absorption processes in plants. A study by Sianipar (2021) suggests that rising air pressure due to climate change has the potential to cause a decrease in FFB production of up to 5%. Correspondingly, changes in air humidity play a crucial role, as they can influence the critical processes of flowering, fruit formation, and proliferation of pests and diseases.

Oil palms require sufficient sunlight intensity to support photosynthesis and fruit formation. The observed changes in climatic parameters have cascading effects on the production of other plantation commodities, such as rubber (Rosana et al., 2020). The optimal air temperature for rubber growth and yield ranges from 25–30°C (Jacob et al., 2022). A temperature increase due to climate change potentially disrupts physiological processes including photosynthesis, respiration, and latex formation. According to a study by Balai et al., (2019) ,a 1°C rise in air temperature alone can decrease rubber latex production by up to 8%. Air pressure is also a determining factor, as its changes influence transpiration and water absorption in rubber plants. Studies from Rosana et al., (2020) found that an increase in air pressure risks reducing rubber latex production by up to 5%.

Optimal air humidity for rubber growth ranges from 65–80% (Priyadarshan, 2017). This humidity fluctuation is critical because it affects stomatal opening, transpiration, and the development of pests and diseases. Furthermore, a decrease in air humidity due to climate change can reduce rubber latex yield by as much as 10%. Beyond rubber, climate change also threatens coffee production. Coffee ideally requires air temperatures between 18–24°C for optimal growth and fruit formation (Pham et al., 2019). Rising temperatures induce disturbances in physiological processes, such as photosynthesis and fruit set. Empirically, research by Angka (2021) and Sarvina et al., (2020), suggests that a 1°C temperature increase can reduce coffee bean production by up to 15%. Similar to other crops, air pressure fluctuations can also affect transpiration and water absorption processes in coffee plants.

Air pressure fluctuations are also a concern for coffee plants. A study by Cassamo et al., (2023), suggests that an increase in air pressure driven by climate change can lead to a reduction in coffee bean yield. Meanwhile, the optimal air humidity for coffee ranges from 70–90%. Changes in this parameter are crucial as they affect the flowering process, fruit formation, and the development of pests and diseases. Research by Legesse et al. (2019) and Girma, (2023) confirms that a climate-induced decrease in air humidity can reduce coffee bean production. Furthermore, coffee requires sufficient sunlight intensity for photosynthesis and fruit formation. Furthermore, climatic impacts also extend to strategic food crops like rice. Changes in air pressure can interfere with the transpiration and water absorption processes in rice plants. Saud et al. (2022), found that increased air pressure risks reducing rice grain production. Similar to other crops, rice requires optimal air humidity (60–80%) for successful yields; fluctuations in humidity influence flowering, grain formation, and pathogen development. A climate-related decrease in air humidity can also directly result in lower rice grain production. Additionally, photosynthesis and grain formation in rice necessitate adequate sunlight intensity. Regarding sunlight intensity, multiple studies (Abubakar et al., 2021; Jacob et al., 2022.; Koh et al., 2020; Krishnan et al., 2011; Oh et al., 2023; Sarkar et al., 2020; Tavares et al., 2018) conclude that an increase in sunlight intensity due to climate change can boost the production of oil palm, coffee beans, rice grains, and rubber latex by up to 10%. It is crucial to note, however, that excessive intensity can induce severe stress in these plants.

Otherwise, increasing sea water temperatures have caused a shift in the distribution of fish species towards the poles and a decrease in marine fish. An increase in the concentration of carbon dioxide ($CO2$) in the atmosphere causes an increase in the acidity (decrease in pH) of seawater, known as ocean acidification. According to a study conducted by (Doney et al., 2020), ocean acidification can disrupt the growth and calcification of marine organisms, including fish and crustaceans, which in turn can affect marine fisheries production. Changes in rainfall patterns and the melting of polar ice caps due to climate change can significantly influence sea water salinity. Research by Nagelkerken et al. (2023) demonstrates that fluctuations in sea water salinity can alter the distribution, growth, and reproduction of marine fish species, ultimately affecting the productivity of marine fisheries. Furthermore, shifts in the intensity of sunlight penetrating the ocean can impact primary productivity (phytoplankton) and the marine ecosystem's food chain. A study by Kwiatkowski et al. (2020) indicates that increased solar radiation intensity due to climate change may boost primary productivity, which subsequently has the potential to influence marine fisheries production (Barange et al., 2018).

To complement the quantitative findings, this research incorporates the results of a Sharing Group Discussion (SGD) convened by the Regional Office of the Directorate General of Treasury (DJPB) of Bengkulu Province. This SGD was designed to gather input and contextual validation from various relevant stakeholders. Attendees of the event included representatives from the Central Statistics Agency, the Climatology and Meteorology Agency (BMKG), the Maritime Service, the Agriculture Service, the Food Crops and Horticulture Service, the Environmental and Forestry Service (LHK) of Bengkulu Province, as well as the research team. These results are in the form of an explanation of the regional government's policy response in mitigating the impact of climate change on potential commodity production, including the plantation, agriculture and marine fisheries sectors, especially in Bengkulu Province. Results are shown through tables. 7 as follows:

Table 7. The Impact of Climate Change to Resources Degradation

Stakeholder	Challenges	Respon Policies and mitigation
BMKG in Bengkulu Province	• Farmers tend to still use traditional weather forecasting patterns, while climate change is increasingly uncertain and difficult to predict. Example: Seeding and planting rice begins in the months ending in "-ber" such as September, November and December • Fishermen's knowledge of potential fish gathering locations, such as the tendency of fish to gather at warm water temperatures	• Periodic and routine climate change outreach to farmers • Creating innovative technology that is useful for detecting the presence of fish • Collaboration between stakeholders to obtain good symmetric information between related institutions/agencies such as the tourism office and others
Maritime Service in Bengkulu Province	• Fishing production tends to decrease due to climate change • Decreased quality of fish eggs	• Marine fisheries in Bengkulu Province have unlimited resource potential (will not run out) due to the condition of the coast which is directly connected to the Indian Ocean. • Improved fishing equipment for fishermen

	• Climate change may affect the size or weight of fish obtained • Fishermen tend to maintain a culture of not wanting to stay overnight at sea • Disturbed fish seedlings	• Training on use of larger vessels • Build FADs every 10 miles so that there is a term "fishermen catch fish, not look for fish" • Feed or seed assistance program for example Lele and Nila
Food Crops and Horticulture Service in Bengkulu Province	• Drought issues • Water needs are very necessary (primary needs) for farmers • The problem of pump fuel is not included in aid so farmers are reluctant to be helped if they have to bear fuel costs	• Program to establish a Food Emergency Task Force (Task Force) to anticipate drought preparedness from the Ministry of Agriculture, TNI-Polri and the Center for Plantation Instrument Standardization (PSIP) • The pumping program is in the form of pump assistance from the center to the regions which are placed in water sources and sucked into rice fields. • Pump irrigation program, namely a pump house from a water source and channeled into a reservoir then distributed back to the horticultural rice fields • Use of a hydraulic pump so no fuel is needed
Environment and Forest Service (LHK) in Bengkulu Province	• The issue of drought is quite long • Quite high rainfall	• There needs to be an evaluation regarding the level of company or producer compliance with pro-climate policies • • Providing incentives as rewards to companies/producers who support the pro-clim program and sanctions for the opposite • • Reactivation of the dam function and maintenance as an alternative water supply

Sources: data SGD processed by author, 2025

Table 5. Panel Data Regression Results with Robustness

Independent	**Dependent: Volume of production**									
	Fisheries		Paddy		Palm Oil		Rubber		Coffee	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Air temparature	-2.48 (4.94)	21.758 (17.224)	-563.04 (438.92)	-4.424 (366.27)	533.25 (323.07)	**981.27** (383.68)**	-6.855 (11.55)	**259.73*** (72.54)**	**13.54* (6.244)**	40.98 (29.48)
Air pressure	0.001 (2.57)	-1.732 (1.815)	**86.89** (21.51)**	-59.383 (70.059)	**30.947* (11.528)**	**84.174*** (14.321)**	3.315 (3.425)	16.90 (13.27)	0.523 (0.496)	-3.403 (2.461)
Wind velocity	-3.53 (2.46)	**25.973** (12.01)**	147.36 (176.90)	158.74 (435.93)	-230.20 (209.71)	**-489.9*** (181.17)**	-6.323 (10.38)	-52.57 (66.16)	-3.276 (3.471)	0.0141 (16.022)
humidity	1.46 (1.35)	2.848 (4.737)	-3.44 (12.82)	-132.65 (92.594)	95.358 (77.529)	131.06 (82.147)	-1.457 (1.646)	9.93 (14.48)	**1.170* (0.672)**	-2.053 (3.451)
Rainfall	0.012 (0.01)	**-0.035*** (0.0059)**	0.453 (0.314)	**-0.573* (0.314)**	0.0848 (0.268)	0.2004 (0.280)	0.021 (0.042)	-0.026 (0.041)	0.0015 (0.005)	**-0.021* (0.0114)**
Radiation	**10.33* (0.478)**	**-3.130*** (0.7178)**	6.779 (21.47)	-56.18 (52.03)	0.884 (17.369)	-12.673 (11.082)	-2.514 (1.611)	-13.84 (11.59)	-0.429 (0.235)	-1.026 (1.864)
R-Squared	0.4338	0.7100	0.6991	0.4770	0.8039	0.7902	0.2054	0.6035	0.0831	0.6499
Total Observation	40	40	40	40	40	40	40	40	40	40

Note: Significance level 1% (< 0.01)***; 5% (< 0.05)**; and 10% (<0.1)* with robustness test. Sign (1) is a fixed effect approach, and (2) is a random effect approach. Panel (i) : Province, (t) : 2015-2022
Sources: Author's calculation based on BPS and SLHI data, 2025

4. CONCLUSION

This study shows that climate variability already reshapes Southern Sumatra's real economy. Using 2015–2022 provincial panels, we find sector-specific sensitivities: paddy output rises with air pressure but falls with heavier rainfall; palm oil benefits from warmer temperatures and higher pressure yet contracts with stronger winds; coffee gains with higher temperature and humidity but is dampened by rainfall; marine fisheries increase with stronger solar radiation; rubber exhibits no statistically robust climate effects at annual-provincial resolution. Model diagnostics favor fixed effects for all commodities except palm oil, supporting within-province identification of climate impacts. Operationally, these results imply near-term adaptation must be commodity-targeted: water management and planting calendars for paddy; windbreaks, heat-stress and flowering management for palm oil; shade/agroforestry and moisture control for coffee; and solar-radiation–aware effort allocation and habitat protection for fisheries. The evidence base remains constrained by small-N panels, annual aggregation, and limited controls for market/technology shocks; future work should employ higher-frequency station data, nonlinear thresholds, spatial econometrics, and scenario-based projections tied to concrete investment choices. Bottom line: without commodity-specific adaptation and better climate services, Southern Sumatra will keep surrendering yield and income to weather rather than productivity—while targeted, province-level measures can defend output and stabilize livelihoods now.

Ethical Approval
Not Applicable

Informed Consent Statement
Not Applicable

Authors' contributions
RN contributed to the conceptualization, research design, data analysis, and manuscript preparation. She also served as the corresponding author and coordinated the submission and review process. A contributed to the development of the research framework, statistical modeling, and interpretation of the results. RAE was responsible for literature review, data validation, and drafting part of the discussion section. BPK contributed to data collection, visualization, and editing of the final manuscript. BAP and S provided policy analysis support and contributed to the interpretation of results from the institutional perspective of the Directorate General of Treasury, Bengkulu Province.

Disclosure Statement
The Authors declare that they have no conflict of interest

Data Availability Statement
The data presented in this study are available upon request from the corresponding author for privacy.

Funding
This study did not receive any external funding.

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